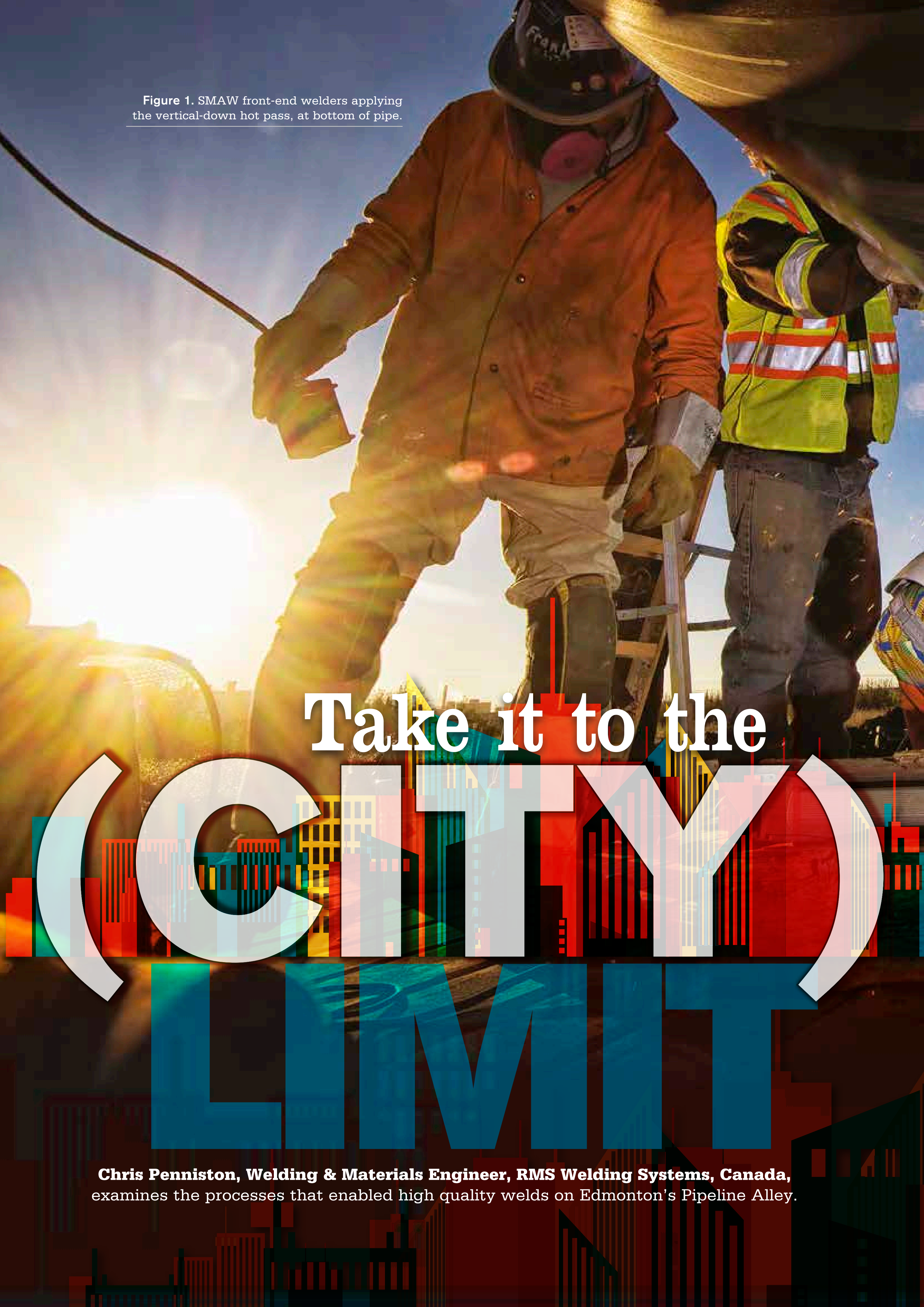

Figure 1. SMAW front-end welders applying the vertical-down hot pass, at bottom of pipe.

Take it to the (CITY) LIMIT

Chris Penniston, Welding & Materials Engineer, RMS Welding Systems, Canada, examines the processes that enabled high quality welds on Edmonton's Pipeline Alley.

Regulatory approval of Enbridge Pipelines (Woodland) Inc.'s application for the Woodland Extension Project was granted in August 2012 by Alberta's Energy Resources Conservation Board (ERCB). At 385 km (240 miles) in total length, the oil pipeline will connect Enbridge's terminal in Northeast Edmonton with its Cheecham Terminal, located about 100 km (62 miles) south of Fort McMurray.

Given the large number of road, rail, water and pipeline crossings within Edmonton's transportation utility and northeast corridors, it was decided that a segment closest to the city would be suited for pre-build construction. At approximately 13 km (8 miles), this pre-build section extends the southern portion of the Woodland Extension Project from Enbridge's Edmonton terminal, to outside the city's northeast limits. Enbridge awarded the construction contract for this pre-build segment to OJ Pipelines Canada, with construction occurring in Autumn 2013.

Welding process and crew configuration

With a large number of crossings along the terrain of this pre-build project, and different types of weld applications, there were a number of considerations made during the conception and development of weld procedures for the project. Welding activities were divided into four general applications. Mainline and horizontal directional drill (HDD) sections were welded by 'pipe gangs', using an internal clamp for fit-up. Sections and ditch tie-ins were welded by section crews using an external clamp for fit-up.

In general, two pipe gangs were assembled. A pipe gang is a relatively large crew that uses a considerable amount of ancillary equipment, enabling high productivity welding of line pipe and heavy wall pipe.

In addition, two section/tie-in crews were utilised. With a focus on versatility, this small nimble crew and equipment configuration is suitable for welding pipe to sidebends and overbends, other special joining applications and configurations, as well as ditch tie-ins.

For all applications, similar process combinations were chosen. The 'front end', consisting of fit-up/clamping and root, hot pass and first fill pass, would weld using the SMAW process. With a large proportion of heavy wall pipe on the project, the use of high productivity welding was appealing. The 'back end', consisting of welding fill and cap passes, was thus welded using mechanised gas-shielded flux-cored arc welding (FCAW-G).

Depending on the phase of the project, different back-end shack (mechanised welding shelters) lineups were used. For instance, more shacks were assigned to pipe gangs at the beginning of the project, with a transfer to more section and tie-in crews toward the end of the project.

Figure 2. Mechanised welding 'shacks' on rig mats.

Figure 3. Crew inspecting the internal line-up clamp.

Pipe gang front-end welding for mainline and HDD

Fit-up was achieved using an RMS pneumatic internal clamp (Figure 3). Spacing personnel, in co-ordination with side boom operators, ensured that acceptable gap and high/low (offset) were achieved during clamp engagement (Figure 4).

The root (Figure 5) and hot pass (Figure 1 and 6) were welded using Miller XMT 304 CC/CV inverter power sources connected to a generator set on a tack rig. As a result of the reduced set-up time, the use of tack rig allows for higher productivity compared to truck-mounted rigs. The same pair of welders applied both root and hot passes in sequence, reducing root/hot interpass time and promoting diffusion of hydrogen out of the weld and heat-affected zone, reducing the risk of hydrogen-assisted cracking (HAC).

For all welds, an AWS A5.1 E6010 (also EN ISO 2560-A E 42 3 C25) root pass was employed. This electrode is considered the North American onshore industry standard for open-gap external root pass welding of CSA Z245.1 Grade 483 line pipe (API 5L and ISO 3183 X70M/L485M equivalent), because it provides predictable and forgiving operating characteristics.

Following the root pass, an AWS A5.5 E8010-G (also EN ISO 2560-A E) hot pass was employed. With the large amount of deposition typically used for the hot pass, the strength level of the electrode is well suited to Grade 483/X70 line pipe. A larger electrode was used along with high current density in order to effectively remove the 'wagon tracks' typically left behind by the root pass.

In order to maximise weld quality, a low hydrogen pass was instituted for the first fill pass. In addition to helping mitigate

Figure 4. Pipe incoming to the internal line-up clamp.

Figure 5. Spacer removing spacing tools while welder applies the root pass.

Figure 6. SMAW front-end welders applying the vertical-down hot pass, at top of pipe.

Figure 7. Mechanised welding operator welding inside a 'shack'.

the risk of hydrogen assisted cracking (HAC) occurrence, the low hydrogen weld metal acts to isolate the underlying cellulosic SMAW passes from the flux-cored arc welding fill and cap passes to be deposited afterward. A pair of welders used rig trucks for welding the first fill pass. An AWS A5.5 E8045-P2 (also EN ISO 2560-A E 46 5 1Ni B 4 5) low hydrogen vertical down (LHVD) electrode was selected for this application. LHVD was chosen over low hydrogen vertical-up (LHVU) electrodes for productivity considerations. Shop trials performed prior to weld procedure qualification found LHVD consumables to be approximately twice as fast as LHVU ones, mainly due to a higher achievable current level along with the larger useable electrode diameters and higher travel speed in the vertical-down progression. However, it should be noted that for implementation of LHVD consumables, a greater amount of training and due care must be devoted to their use.

Section and tie crew front-end welding for tie-ins

Fit-up was achieved using an external clamp for tie-ins. The root and hot pass were applied in sequence as above, although rig welding trucks were used rather than a tack rig. This same pair of welders also applied the first fill pass. For welding the first fill for tie-ins, AWS A5.5 E8018-C3 LHVU electrodes were used. The LHVU electrode was employed in order to better mitigate the expected greater variance of fit-up for these joints.

Section and tie crew front-end welding for sections

Fit-up was achieved using an external clamp for sections. Depending on fit-up conditions, either the LHVD or LHVU first fill SMAW consumable was used. For sections, as with tie-ins, all three front end passes were performed in sequence, by the same pair of welders.

Pipe gang and section & tie-in crew back-end welding

With a large proportion of heavy wall pipe on the project, mechanised flux-cored arc welding with rutile AWS 'T-1' consumables was used for the fill and cap pass. A proven and popular high deposition and low downtime process, the slag acts to support the weld puddle, allowing high deposition rates in the vertical-up progression. The resulting welds typically display a low tendency for formation of lack of fusion defects, while providing high production rates and low cycle times, when compared to competing processes. Additionally, after deposition of a pass, the slag is generally self-peeling, making for short interpass time delays.

An overmatching consumable with a proven prior-project history of exhibiting high charpy v-notch absorbed energy values was utilised, bearing the classification AWS A5.29 E111T1-K3MJ-H4 (also EN ISO 18276-A T 69 4 2NiMo P M 2 H5). A 75% Argon, 25% CO_2 gas mix was employed, assuring a stable arc with predictable and consistent spray-like metal transfer. Given the large proportion of heavy wall project pipe, an overmatching consumable would assure toughness, strength and a fine microstructure, despite elevated heat inputs and/or interpass temperatures to be encountered from near-continuous welding that would occur on many project joints.

In order to protect the mechanised welding operation, shacks were used (Figure 7). Refer to Figures 8 and 9 for a view of the mechanised welding. Again, two shacks were employed by the two pipe gangs welding mainline and HDD sections, and their production approximately matched that of the front-end SMAW crew. Depending on wall thickness (WT), different deposition strategies/balance between the lead and trail shack were implemented in order to maximise productivity. Wall thicknesses welded by the pipe gangs were from around 12 mm (0.472 in.) for the mainline pipe, with 15.9 mm (0.626 in.) and 20.4 mm (0.803 in.) WT used for thicker sections and HDDs.

After lowering in, as shown in Figure 10, ditch tie-ins were performed. See Figure 11 for a view of a mechanised welding shack being prepared for welding of a ditch tie-in joint. One shack was employed for both section and tie-in crews, with welding-out being nearly continuous for a given joint. Various wall thicknesses were tie-in welded depending on the components being joined.

Figure 8. Mechanised welding operator welding vertical-up, at the bottom of the pipe.

Figure 9. Mechanised welding operator welding vertical-up, at the side of the pipe.

Figure 10. A pipeline section being lowered-in.

Cycle times

As a result of the fixed number of front-end passes employed, cycle times were unaffected by wall thickness. However,

Figure 11. A shack being prepared for mechanised welding of a ditch tie-in joint.

variations were found depending on the application type. Front-end SMAW welding for mainline and HDD welding by the pipe gangs, incorporating the quicker LHVD first fill pass, and two pairs of welders welding in succession, took approximately 30 mins/joint. Front end times for section welds, generally employing an LHVD first fill, and applied by a single pair of welders, took approximately 40 mins. Front end times for tie-in welds, where the first three passes were welded by the same pair of welders, and incorporating the slower LHVU first fill pass, took approximately 55 mins on average.

Back end mechanised FCAW-G welding cycle time was dependant on wall thickness, and unaffected by the type of crew configuration or application. Approximate average cycle time for fill and cap pass welding on 12 mm (0.472 in.) WT was 35 mins; for 15.9 mm (0.626 in.) WT was 50 mins; and for 20.4 mm (0.803 in.) WT was 90 mins.

Quality figures

Phased-array automated ultrasonic testing (PAUT) was employed as the primary nondestructive examination (NDE) method for the project. The benefits of this technique include quick examination cycle times for various wall thicknesses; minimal safety hazards to personnel, particularly when compared to alternatives such as radiographic testing; and a high probability of detection (POD) for planar flaws. Planar flaws are generally considered the most detrimental type to weld integrity, because of high stress intensity factors resulting from their geometries.

CSA Z662 workmanship weld acceptance standards were employed because of the use of manual welding methods for front end welding, and additionally, because of the short distance the project traversed. The high rate of fusion of the FCAW-G process makes the achievement of workmanship quality welds readily achievable.

With a total of 490 mainline and HDD welds, 67 section crew welds, and 120 ditch tie-ins welds, 22 welds required repair in total. This corresponds to a repair rate of 3.2%. Rejectable weld defects were mainly located within the SMAW root.

Conclusions

The use of mechanised FCAW-G on the Woodlands Extension pre-build project allowed high quality, low hydrogen content and high deposition welding to occur. Compared to traditional cellulosic 'stovepipe' welding, this type of weld using the employed consumables possesses higher weld metal Charpy absorbed energy values and significantly fewer stop/starts. In addition, with mechanised weld parameters (current, voltage, travel speed, weaving, etc.) being recorded automatically, and ranges locked to qualified ranges, mechanical properties are assured more confidently, as compared to manual welding alternatives.

In summary, Enbridge, OJ Pipelines and RMS Welding Systems worked together to ensure welding and construction was carried out to a high standard, using productive and high quality processes. And that's taking it to the city limit, for a job well done.